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Battelle

Probable Levels of R&D Expenditures in 1987

Forecast and Analysis

This Battelle report is based upon a continuing study of U.S. expenditures for research and development. It was prepared by Drs. Jules J. Duga and W. Halder Fisher of Battelle's Columbus Division. Parts of the data presented here were derived from such sources as the National Science Foundation, the McGraw-Hill surveys, and others.

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1987

SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be $127.4 billion during calendar year 1987. This is an increase of 7.4 percent over the $118.6 billion that the National Science Foundation (NSF) estimates actually will have been spent in 1986.

2. Costs of performing R&D are expected to rise almost 3.0 percent from 1986 to a 1987 index level of 131.25 (1982 = 100 percent), absorbing a considerable amount of the increased funding. However, this implies a *real* increase in expenditures of approximately 4.3 percent, reaching a new peak in total real funding of R&D (Figure 3).

3. Federal government funding in 1987 is expected to be about $59.5 billion (46.7 percent of total), an increase of $4.2 billion (7.6 percent) from 1986. Performance of R&D by the Federal government will represent $14.7 billion (11.5 percent), an increase of $700 million (5.0 percent) over 1986 estimates.

4. Industrial funding in 1986 is expected to be nearly $63.8 billion (50.0 percent of total) representing an increase of $4.28 billion (7.2 percent) over that of 1986. Performance of R&D by industry is expected to rise to over $93.6 billion (73.5 percent of total), an increase of $6.63 billion (7.6 percent) over 1986.

5. Estimates of Federal government versus industry support for the R&D performed by each of several broad industrial sectors are included in the 1987 forecast. Drawing upon historic trends, the anticipated total performance by the industrial sector has been calculated; first within each of 17 major industrial groups, and then according to whether that performance is supported by Federal government or industrial funds. These estimates are shown in Table 4.

6. In 1987, the Federal government is expected to support almost three-fourths of the aerospace industry's R&D activity, approximately one-third of electrical machinery/communications, and slightly more than one-fourth of the R&D in the primary metals industries. All other broad manufacturing industry classes are expected to be supported primarily by industry funds. These ratios range from 81 percent for the ground transportation industries up to 100 percent for the textile and the food and beverage industries. Overall, 33.0 the food and beverage industries. Overall, 33.0 percent of industrial R&D will be Federally funded with the remainder funded by industry.

7. Academic and other nonprofit institutions taken together are expected to fund $4.2 billion of R&D in 1987 (3.3 percent of total) and to perform almost $19.1 billion (15 percent). Both of these figures represent significant increases in the percentage of support and performance over the 1986 NSF estimates. These figures also include the Federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.

8. Within the nonprofit category, colleges and universities are expected to account for 65.5 percent of the 1987 funding and 81.3 percent of the R&D performance; both of these figures represent small increases over the 1986 NSF estimates.

9. The costs of R&D performance have risen steadily in all four categories (Federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven partially by overall inflation, but primarily by the so-called "sophistication" factor.

10. The trends in real R&D effort (see Figure 3) continue to move upward, as they have over much of the past decade. Since 1976, real R&D effort has increased at a 10-year average rate of 4.26 percent, and the projections for 1987 suggest that the 11-year average rate will be essentially unchanged. Battelle estimates that during the next few years real R&D activity will increase at an average annual rate of approximately 3.5 percent, tapering off slowly from the present growth.

11. Significant factors that appear to be influencing trends in the support and performance of R&D include:

    (a) Federal government emphasis on defense programs will have a continued influence on total R&D support and the principal industrial performers; these emphases will be felt primarily in the aerospace, electronics, and communications industries.

    (b) Energy-related R&D programs will continue to experience mixed Federal support, with increased funding in basic energy sciences and defense-related energy programs. In addition, health-related R&D will receive a significant boost over previous levels of funding.

(c) Uncertainties over the new tax laws will have a small effect on industrial support of R&D. Greater impacts may be felt as a result of industrial restructuring and a renewed interest in short-term profits.

(d) University self-funding of R&D is expected to continue to show real increases, partially as a result of continued industrial "directed programmatic endowment" support of basic and applied research, part of which will be influenced by the new tax laws.

(e) The Gramm-Rudman-Hollings Act did not affect the rate of growth of government-funded R&D to the extent anticipated.

12. As a special feature, this report provides a preliminary forecast of R&D funding levels in 1988. The preliminary data show the total U.S. expenditure for R&D in 1988 will be $134.5 billion (uncorrected for inflation).

13. Continuing a feature instituted in last year's Forecast, this report contains a preliminary detailed line-of-business R&D estimate which covers 130 productive sectors of the U.S. economy.

ANALYSIS AND FORECAST

Since research and development (R&D)* is one of our prime concerns, Battelle has an intense and abiding interest both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities—technological, economic, and social. Accordingly, Battelle has carried on a continuing study into the forces affecting R&D activities and into their sources of support. Among the tangible products of this research has been a series of annual analyses and forecasts of R&D expenditures. This report represents the latest in that series.

The content of this report has evolved over the years in an attempt to supply information Battelle considers useful to the R&D community, but has not been adequately supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the McGraw-Hill *Annual Survey of Business Plans for R&D.*

NSF *Patterns* had been published during the first half of each year (usually in April) and had included a forecast of that same full year's R&D expenditures by source of funds and by performer. However, since the fiscal year now begins in October, *Patterns* contains both the preliminary data for the closing fiscal year and estimates for the two preceding years. Recently, the publication of *Patterns* has been delayed until late in the calendar year, and it contains better estimates of the R&D funding and performance for that same year.

The McGraw-Hill surveys (usually published at about the same time as *Patterns*) make forecasts—the 1986 Survey (published in May) made forecasts for 1986 and 1988—but are confined to the performance of the industrial sector and do not separate Federal government from industrial funding.

The Battelle report, usually published in December, has been intended to fill the niche left, by emphasizing the coming year (in this case, 1987) and industrially funded R&D. Other relevant information, gleaned from many sources, has also been included.

Beginning with the 1980 forecast, we have included a forecast of industrial R&D expenditures according to broad industry class, along with the estimated distribution of those funds between industrial and Federal sources. This added feature provides the background necessary to understanding the way Federal policy can affect industrial innovation, spur industrial support of its own R&D efforts, and enhance the longer-term international competitiveness of U.S. industry. Although related aspects of productivity, training and manpower needs, tax incentives, balance of payments, and other concerns are not predictable, we anticipate that continued analysis of this subject will help identify both the promises and the problems associated with industrial responses to future opportunities.

Continuing the practice initiated in the 1984 Forecast, we present estimates which cover a *two*-year forecast to 1988.

Historical Trends in R&D Funding and Performance

Although the NSF data series began in 1953, we begin our analysis with 1960 data. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1986 are shown in Table 1.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D-supportive funds were provided by the Federal government; 33.4 percent were provided by industry; and 1 percent each came from the academic community and from other nonprofit organizations.

Between then and 1984, Federal funding rose to 66.5 percent in 1964, and has slowly declined to 46.0 percent

*The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

TABLE 1. SOURCES OF R&D FUNDS AND PERFORMERS OF R&D, UNITED STATES, CALENDAR YEARS 1960-1986

(Millions of Current Dollars)

		Sources of Funds				Performance [a]			
Year	Total R&D	Federal Gov't	Industry	Colleges and Universities [b]	Other Nonprofit [c]	Federal Gov't	Industry	Colleges and Universities	Other Nonprofit [c]
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,928	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,892	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,018	19,914	17,694	810	600	5,769	26,997	4,876	1,376
1977	42,783	21,594	19,629	888	672	6,012	29,825	5,451	1,495
1978	48,129	23,876	22,450	1,037	766	6,811	33,304	6,342	1,672
1979	54,933	26,815	26,081	1,200	837	7,417	38,226	7,296	1,994
1980	62,593	29,451	30,911	1,323	908	7,632	44,505	8,306	2,150
1981	71,840	33,405	35,944	1,520	971	8,425	51,810	9,305	2,300
1982	79,328	36,505	40,096	1,702	1,025	9,141	57,995	9,767	2,425
1983	87,178	40,667	43,514	1,864	1,133	10,582	63,403	10,518	2,675
1984	97,379	45,263	48,911	2,000	1,205	11,586	71,227	11,591	2,975
1985[d]	108,800	50,915	54,385	2,200	1,300	13,150	79,500	12,900	3,250
1986[d]	118,600	55,250	59,475	2,500	1,375	14,000	87,000	14,200	3,400

Source: National Science Foundation, National Patterns of Science and Technology Resources, 1986; NSF 86-309

(a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.
(b) As sources of funds, these include state and local government funding.
(c) All other nonprofit institutions.
(d) Preliminary estimates by NSF.

in 1982 and has fluctuated since that time.** Over that same period, industrial funding declined to 31.2 percent in 1964 and rose to 50.6 percent in 1982, with a small decline to 50.0 percent expected in 1987. The two nonprofit sectors have risen gradually, colleges and universities to 2.2 percent and other nonprofits to almost 1.6 percent, although nonprofit support has declined steadily over the past nine years.

Through 1982, trends showed a continued increase in industrial funding as a percent of total funding, with a corresponding decrease in Federal sector funding. Over the past four years, however, the relative contributions by industry and the Federal government have remained essentially constant. This is largely due to significant increases in defense spending, industrial response to a healthier economy, and other initiatives (see the later discussions on the role of industry).

Although the Federal government had been the major *source* of R&D funds from 1953 to 1979, its dominance of R&D funding has been eroded since 1980. Industry is by far the major *performer* of R&D. Federal performance of R&D rose from 12.7 percent in 1960 to 16.1 percent in 1972 and has been fluctuating since that year, albeit at a generally decreasing percentage. Industrial performance reached a high point of 79 percent in 1957, and

**Note that NSF data for 1985 and 1986 are "estimated". However, comparisons among the series of *Patterns* reports reveals that adjustments are made on earlier years' figures, with such adjustments carrying back as far as 1978. Thus, many of our calculations that are dependent upon long-term figures will vary from one year to the next.

drifted steadily downward to a low of 68.6 percent in the early 1970's; more recent trends suggest a slow increase in the proportion of industrial performance, which has risen to nearly 74 percent. While the academic community's performance varied between 6 and 8 percent prior to 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent levels reaching 12 percent. Over the past few years (since 1980) this sector's share has been declining slightly, although there is a more recent tendency to reverse this decline. Such a reversal has resulted from industrial initiatives (see later). For most of the 1960–80 period, other nonprofit organizations, including Battelle, had increased their share of performance of R&D from 2 to about 3.5 percent of the total, again with recent declines in that share.

It should be noted that Federal funding supports research performed by all four sectors. Currently, almost one-fourth of Federal R&D funding supports intramural R&D; over half supports industry; approximately one-fifth supports colleges and universities; and the rest, slightly more than 4 percent, supports other nonprofits. Industry absorbs almost all of its own funding, either intramurally or by contracting with other industrial performers; its contracts and grants to colleges and universities slightly exceed those to other nonprofit institutions. Other nonprofits finance both themselves and academic institutions about equally, while colleges and universities absorb all the funds they originate.

In Table 1 we summarize the latest NSF time series on the sources of R&D funding and the volumes of R&D performance. During the interval since 1960, total R&D dollars (not adjusted for inflation) have increased almost ninefold. Federal funding has multiplied by a factor of 6.3 and Federal performance has increased by a factor of 8.1. In terms of constant dollars, total R&D expenditures almost doubled from 1960 to 1986, and Federal performance has increased by 26 percent (see Table 6). Using the same deflator for Federal funding that we used for total expenditures, real Federal funding increased by about 42 percent.

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support for their own R&D activity, with the remainder coming primarily from the Federal government. In recent years, this ratio has tended to decrease, not only as a result of some reduction in selected Federal programs but also due to an increase in academic funding. This latter is largely a "bookkeeping" artifact created by the manner in which university funds are ascribed to the universities, rather than to the ultimate original sources. More will be said about this in later sections of the Forecast.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, manifested by a leveling in current-dollar Federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more nearly like that before 1968. As anticipated in last year's Forecast, there is a continued growth of total real R&D support, although the rate of growth has slowed and is expected to decrease.

The continuing transition in the support and performance of R&D, to which we referred in the 1983 and 1984 forecasts and analyses, has had a significant impact on the patterns within the overall R&D enterprise. The Federal government has developed and maintained—albeit over the strong objections of both academia and some industry—a posture that has influenced the type and extent of Federal support. There is perhaps no stronger evidence of this than the major restructuring of Federal programs in energy and social services. In each of these cases, it has not been merely the change in Federal *actions* that has had an impact on the research community, but it is more the change in *philosophy* which has permeated the scene.

This is evidenced in the encouragement of R&D within the private sector, the determination to let the marketplace decide the most fruitful areas for private investment, and the return to the state and local levels of government those functions which are deemed most appropriate for state or local action.

Presently, the strongest Federal action, as we shall see in later sections of this forecast and analysis, remains in areas of fundamental concern to the central government: (1) national defense; (2) technological competition from our trading partners; (3) health; and (4) the environment for economic growth. The extent to which Federal actions can influence these areas will continue to be dependent upon a number of different factors, including the response to expanded military and/or diplomatic tensions throughout the world, and the pervasive question of the massive national debt.

Forecast for 1987

During calendar year 1987, Battelle expects the total current dollar volume of R&D activity to be higher than the level estimated by NSF to be achieved in 1986. A comparison of Battelle's 1987 forecast with the last available NSF estimates for 1986 is shown in Table 2. The 1987 forecast is shown in its historical setting in Figure 1.

Referring to Table 2, we estimate the total calendar year 1987 R&D volume to be $127.4 billion, a 7.4 percent increase over the NSF estimates for 1986. It is

TABLE 2. ESTIMATED R&D EXPENDITURES BY SOURCE OF FUNDS AND BY PERFORMERS, U.S. CALENDAR YEARS 1986 AND 1987

(Millions of Current Dollars)

Source of Funds	Performer				Source Totals	
	Federal Government	Industry	Colleges and Universities	Other Nonprofit	Dollars	Percent of All Funds
1986 NSF ESTIMATES						
Federal Government	14,000	28,500	10,350	2,400	55,250	46.58
Industry	—	58,500	600	375	59,475	50.14
Colleges & Universities	—	—	2,500	—	2,500	2.10
Other Nonprofit	—	—	750	625	1,375	1.15
Performer Dollars	14,000	87,000	14,200	3,400	118,600	100
Totals Percent	11.80	73.35	11.97	2.86		
1987 BATTELLE FORECAST						
Federal Government	14,700	30,954	11,300	2,500	59,454	46.66
Industry	—	62,673	660	420	63,753	50.03
Colleges & Universities	—	—	2,750	—	2,750	2.15
Other Nonprofit	—	—	800	650	1,450	1.13
Performer Dollars	14,700	93,627	15,510	3,570	127,407	100
Totals Percent	11.53	73.48	12.17	2.80		
PERCENTAGE INCREASES OVER 1986 ESTIMATES						
Federal Government	5.00	8.61	9.18	4.17	7.61	
Industry	—	7.13	10.00	12.00	7.19	
Colleges & Universities	—	—	10.00	—	10.00	
Other Nonprofit	—	—	6.67	4.00	5.45	
Performer Totals	5.00	7.62	9.23	5.00	7.43	

expected that part of this increase will be absorbed by continued inflation (which we estimate to be 3.0 percent from 1986 to 1987 for R&D).

In connection with this forecast, several important factors must be recognized. First, the total current-dollar projected increase includes an inflation factor that depends significantly on the inflation rate as it specifically applies to R&D. As will be noted in the discussion of the Cost of Research Index, this inflation factor is fundamentally different from that associated with the more familiar consumer price index.

In addition, it is apparent that concerns over the Federal budget will influence the remaining appropriations bills for the 1987 Federal budget. Furthermore, since part of the calendar year 1987 will come during the next fiscal year (1988), the budget process throughout this current calendar year will have a continuing effect on total expenditures.

Finally, industrial support for R&D will continue to be affected by previous years' sales and earnings and should be expected to increase at a substantial rate. The passage of the new tax laws, with a modified continuation through 1988 of the R&D tax credit, could have a direct effect on the extent to which industry supports R&D. However, as has been argued in previous Forecasts, the support of R&D should not stem from a desire to decrease tax liabilities: it is, of course, more logical to increase R&D expenditures in search of long-term survival and profitability.

In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry", we see that the total amount of R&D expected to be performed by industry in 1987 will be $93,627 million. Of this, almost 1,000 million will be funded by Federal agencies, and over $63,000 million by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about $63,750 million

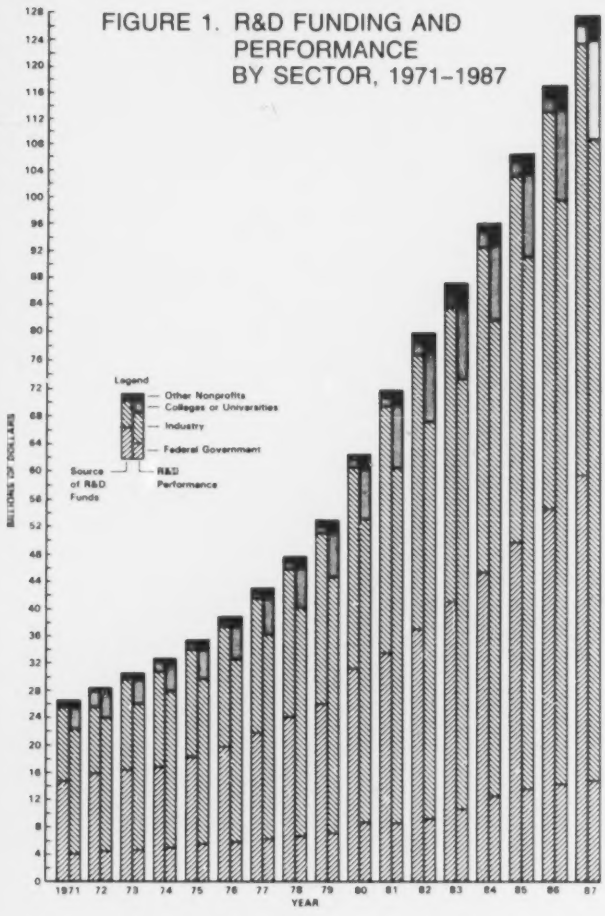
FIGURE 1. R&D FUNDING AND PERFORMANCE BY SECTOR, 1971–1987
BILLIONS OF DOLLARS
YEAR
1971 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Legend
Other Nonprofits
Colleges or Universities
Industry
Federal Government
Source of R&D Funds
R&D Performance

See Tables 1 and 2. 1971–1986 estimates by NSF; 1987 projected by Battelle's Columbus Division.

of R&D. Of this, $62,670 million will be performed by industry, $660 million by colleges and universities, and $420 million by other nonprofit organizations. Included within the "Industry/Industry diagonal" element is that research and development which is supported by one industrial organization and performed by another.

Continued inflation is expected to characterize 1987, although the rate, as experienced in R&D, appears to be declining. In addition, there are many intangibles that favor continued increases in support; such as the increased feeling on the part of both Federal and industrial decision-makers that R&D is vital to long-term economic health. The NSF estimated that current dollar total R&D activity rose by 9.0 percent from 1985 to 1986; we project a smaller increase, 7.42 percent, from 1986 to 1987. As will be shown in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change. Defense-, science- and technology-based problems; considerations of economic development; and foreign competition are expected to provide the major impetus for change. The proportionate composition of both funding and performance will change very little. The Federal government will account for 46.7 percent of the total funding, as compared with 50.0 percent from industry. Industry will account for almost three-fourths of total performance. These two distributions for 1987 are summarized in Figure 2.

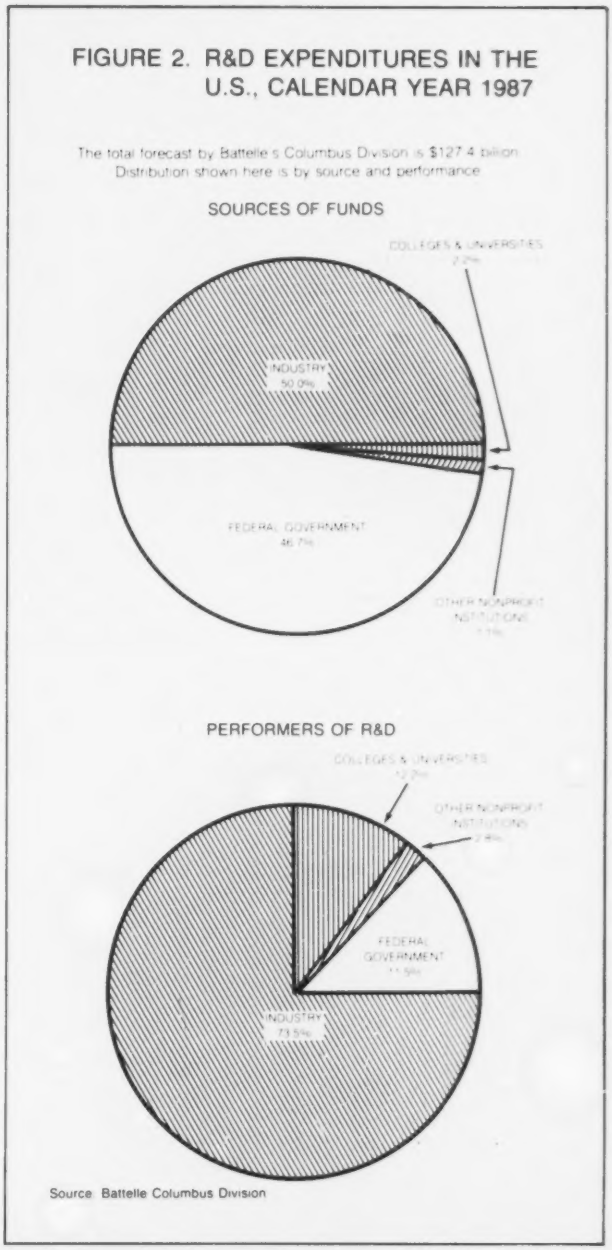
FIGURE 2. R&D EXPENDITURES IN THE U.S., CALENDAR YEAR 1987
The total forecast by Battelle's Columbus Division is $127.4 billion. Distribution shown here is by source and performance.
SOURCES OF FUNDS
COLLEGES & UNIVERSITIES 2.2%
INDUSTRY 50.0%
FEDERAL GOVERNMENT 46.7%
OTHER NONPROFIT INSTITUTIONS 1.1%
PERFORMERS OF R&D
COLLEGES & UNIVERSITIES 12.7%
OTHER NONPROFIT INSTITUTIONS 2.4%
FEDERAL GOVERNMENT 11.5%
INDUSTRY 73.5%
Source: Battelle Columbus Division

The Role of Federal Agencies

Since Federal funding was historically the major source of R&D support (although it has been increasingly outdistanced by industrial support since 1980), the forces likely to affect Federal R&D budgets in Fiscal Year 1987 and beyond are important in the present forecast. The Budget for Fiscal Year 1987, which began on October 1, 1986, continued the emphasis of the earlier Reagan years and set the stage for what might have been significant changes in subsequent years.

The decline in the rate of growth had been suggested in last year's Forecast and is occurring, although for a mixed set of reasons. Earlier predictions from many quarters regarding the impact of the Gramm-Rudman-Hollings Act have not been fulfilled: R&D seems to have fared well both in the Administration and in Congress.

This is not to say, however, that researchers and research managers should be complacent, since the continued pressure caused by the deficit will bring about changes in the not-too-distant future. The slowing of the rate of growth of R&D should surely continue over the next two, and perhaps three, years.

In terms of both hardware and research, the significant increase in defense spending will be continued by the Administration's commitment to new weapons systems and the Strategic Defense Initiative (SDI). Furthermore, preliminary budget plans through 1991 set a direction that suggests continued emphasis in this area, although perhaps with a decline in the rate of growth.

Battelle projects that Federal funding in calendar year 1987 will likely reach a level of $59.5 billion. This figure is based upon: (1) recent trends in Federal budgeting, as reflected in NSF data series on R&D funding; (2) the relationship between Federal funding and Federal obligations; (3) the fact that three calendar quarters' funding will be determined by the FY 1987 appropriation; and (4) the modification of selected mission agency activities.*

The R&D-Minded Agencies

The big-money agencies in terms of total 1987 Federal R&D funding will include the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the Department of Health and Human Services (HHS). Among the smaller agencies, the important suppliers of funds for extramural R&D are the NSF, the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), the Department of the Interior (DOI), the Department of Commerce (DOC), and the Department of Transportation (DOT). Estimated shares for conducting R&D in the early proposed budgets for FY 1987, and comparative estimates of the FY 1985 and FY 1986 plans are:

	1985 Actual Authority	1986 Estimated Authority	1987 Estimated Authority
DOD	63.11	65.04	69.72
HHS	10.97	10.37	8.9
DOE	9.79	9.56	7.67
NASA	6.68	6.54	6.39
NSF	2.7	2.51	2.45
DOA	1.9	1.73	1.47
DOI	0.77	0.7	0.56
DOC	0.78	0.69	0.48
EPA	0.61	0.61	0.48
DOT	0.85	0.6	0.44
All Other	1.84	1.65	1.44

It is obvious from this listing that DoD continues to dominate the Federal scene, accounting single-handedly for about two-thirds of the R&D budget. The Big Four (DoD, NASA, DOE, and HHS) account for 92.7 percent of anticipated Federal R&D expenditures. The next six largest R&D-supporting agencies account for only 5.9 percent, and all others combined account for approximately 1.4 percent.

Functional Categories

Although some of the important R&D agencies are primarily devoted to a single function, many are multifunctional. The NSF lists 16 functional categories, of which the most important have the following shares of 1985–87 budget authorities:

	1985*	1986**	1987**
National Defense	67.5	69.1	73.8
Health	10.8	10.2	8.8
Space Research/Technology	5.4	5.4	5.2
Energy	4.7	4.8	2.8
General Science	3.7	3.4	3.4
Transportation	2.0	1.7	1.5
Environment and Natural Resources	2.1	1.9	1.5
Agriculture	1.6	1.5	1.2
All Others	2.2	2.0	1.8

*Actual
**Estimates

*Note that this estimate applies only to spending for the *performance* of R&D, and does not include any spending for R&D *facilities*.

The remaining functional fields, each receiving less than 0.5 percent of the total R&D budget, are: education, training, employment and social services; community and regional development; international affairs; veterans' benefits and services; commerce and housing credit; income security; administration of justice; and general government. Altogether, these smaller fields account for only 1.8 percent of the total.

As had been expected in earlier forecasts, major increases in R&D expenditures will support national defense. There will be some modest increases in other areas, and slight increases in many agencies or functional areas. However, as a fraction of *total* Federal R&D, almost all other agencies and functional areas—except for defense and space—will show relative (real) declines.

The continued increase in defense-related R&D derives from the development and acquisition of more advanced major weapons systems, and the Administration's commitment to highly sophisticated space-deployed defense approaches. The overall SDI program will continue to be heavily supported, although not quite at the levels requested by the Administration. The technical problems are quite formidable, but the complexities of such problems are not the only driving forces for increased expenditures. The commitment to pursue SDI-related R&D is presently well-established and is expected to continue in spite of whatever progress is made in arms control negotiations over the near term.

The success of the SDI program is intimately tied to the total space program. Earlier editions of the Battelle Forecast predicted that significant changes in the NASA R&D budgets were expected as a result of the conversion of the shuttle program from a research to an operational phase. The tragic loss of the *Challenger,* coupled with other launch vehicle failures and the subsequent retrenchment and reexamination within NASA, will most likely affect NASA budgets and programs. There is little doubt that a new shuttle will be constructed to replace the *Challenger.* Also, increased emphasis will be placed on expanding the shuttle fleet. Other NASA programs, such as the orbiting telescope and the space station, might proceed according to near-original schedules by addition of another craft to the shuttle fleet. The supplemental funds required would probably not affect the R&D budget as such. However, lacking such funds, the R&D programs that lead toward the utilization and support of new ventures in space would most likely be spread over a greater period of time, resulting in an effective decrease in NASA-funded programs.

From 1969–70 to 1973–74, year-to-year changes in R&D budgets favored civilian programs over defense/space. Beginning with 1974–75, emphasis has tended to shift back toward defense and space, especially the former. Throughout the 1970s, the funding of energy-related R&D generally grew by larger increments than that of space or of most other civilian programs. It is expected that Federally supported energy-related research and demonstration programs will continue to decline, except for that portion which supports direct national defense interests. As has been the case in the recent past, energy programs which involve short-term and/or low-risk R&D will probably have to be financed by private industry.

Factors Affecting Future Federal Support

There appears to be a continuing effort on the part of the Federal government to increase funding of R&D, in terms of both support to basic national needs and the broadening of the technological base on which future growth is predicated. National security, reflected in the DoD budget, is seen as a principal driving force in furthering R&D spending. Economic growth, founded upon both basic and applied research, is expected to remain as an objective which requires direct and indirect Federal support, with greater emphasis on the latter.

Federal efforts in energy research will continue to serve basic research that is inappropriate for industrial support, or that represents such long-term investments that no industrial applications are expected in the near future. Additional emphasis on high-energy basic physics research may be forthcoming, with plans for the next generation of particle accelerators already under way. There is a growing interest—expressed generally by the high-energy physics community, and specifically by major universities and state governments—in the Superconducting Super Collider (SSC). While major construction funds would be required over the next few years, operating and research budgets for SSC should not be significant for the remainder of this decade and into the next.

There are indications that industrial support will be growing in biological sciences (as is evidenced by the major increases in industrial funding at universities), and the Federal government will continue to commit substantial resources toward this and allied fields. Budget-trimming efforts, especially as they apply to health and agriculture, have been largely cosmetic in recent years; they generally have been offset by Congressional action to reinstate various programs in such areas.

Over the past few years, there was concern that Federal funding of R&D might shift from extramural contract/grant support to intramural research performance utilizing the capabilities of the extensive Federal laboratory network. In addition, concern could just as well be directed at the support of research in Federally Funded Research

and Development Centers (FFRDCs). There is little evidence that any shift from extramural to intramural programs had been made through 1986. Furthermore, we anticipate that any such changes would be relatively small, and slow in coming. The shares in Federal funding of both the truly intramural and the university-operated FFRDCs have, in fact, been declining over the past few years, as shown below:

Percentage of Federal Funds Expended

	Federal Laboratories	Federal Laboratories and University-Operated FFRDCs
1978	28.5	35.7
1979	27.7	34.9
1980	25.9	33.5
1981	25.2	32.7
1982	25.0	31.8
1983	26.0	32.8
1984	25.6	32.5
1985	25.8	32.5
1986	25.3	31.9

The Grace Commission report, supplemented by the studies of the Packard Report, provided estimates of considerable cost savings that could result from modifications in the manner in which the business of government is conducted. Among these recommendations were inferences relative to the disposition of the Federal laboratories and—by extension—the FFRDCs.

The arguments for change within both types of institutions usually are made in terms of cost savings that result from industrial management, and of accelerated translations of research from laboratory to the marketplace. Conversely, the arguments against change reflect concern about private ownership and exploitation of publicly supported R&D and intellectual property, as well as the potential estrangements of laboratories from the mission agencies they are intended to support.

Although slow in coming, efforts are under way to transfer research responsibilities from the government to the private sector. The negotiation process is quite complex, involving difficult issues which relate to personnel practices, information dissemination controls, and the like. However, over the next decade, a significant number of institutions are expected to undergo such a conversion.

Along with the developments already discussed, continued effort is being made to promote Federal laboratories as resources available to both Federal and non-Federal markets. However, there are conflicts among the various actors that may influence the outcome of this effort. While Federal regulations permit and encourage response by Federal laboratories to external needs, there are also several real and perceived restrictions. Whether Federal laboratories will be more heavily involved in R&D as a result of the Stevenson-Wydler Act, PL 96–480, remains to be seen. As of this writing, there is little evidence that the Federal laboratories are heavily involved in "external" activities. To the extent that they are, there are no reliable statistics regarding the support (on a reimbursable basis) or performance of R&D outside the laboratories' specific missions.

Defense-related Federal funding has increased dramatically since 1980. From FY 1967 through FY 1980, defense R&D fluctuated between 48.9 and 53.6 percent of the total Federal R&D budget. Since FY 1980, however, this proportion has risen to 73.8 percent, representing a compounded increase in share of 5.6 percent per year. This is in contrast to the proportion of the total Federal budget devoted to defense, now less than 30 percent of total Federal outlays, and growing at a compounded rate of only 3.3 percent.

One cannot overlook the impact that Federally sponsored R&D has had on the national economy, as well as the impact it could have if properly managed. Major government-sponsored programs in defense, space, health, energy, and other areas have not only served to assist in fulfilling the fundamental responsibilities of the central government, but they have also served to spur the development of U.S. industry in almost all sectors of the economy. The implementation of research results—many of which were originally supported by Federal funds—has created an economy with strength and versatility to match any found in the world. The extent to which this resource can be and has been used is influenced by a vast array of factors, such as the restrictions placed on the use of intellectual property, the complexity of tax laws, and the demands and expectations which are inherent in a free-market, public-ownership economy.

As Federal efforts are made to enhance the competitiveness of U.S. industry, it is appropriate to point out that the Federal government cannot do it all, and should not be expected to. The responsibilities for increasing productivity, for diversifying the products of manufacturing, and for meeting the challenges by other countries rest equally on all elements of both the public and private sectors. When faced with an interlocking worldwide economy in which developing countries are expanding their own presence in the market, it is incumbent on the Federal government to (1) maintain a posture of continued R&D investment, creating an improved stockpile of usable technological outputs and (2) provide an atmosphere wherein the fruits of these investments can be more readily adopted and adapted for commercial benefit.

The Role of Industry

NSF data indicate that since 1980 industrial support of R&D has been greater than Federal support. Battelle projects this will continue in 1987. As has always been the case, industry will be by far the predominant R&D performer.

During 1986, the NSF has estimated that industry would provide 50.1 percent of total funding and perform almost 73.4 percent of all R&D work (see Table 2). Battelle's forecast for 1987 changes these shares almost imperceptibly to 50.0 and 73.5 percent, respectively.

The NSF data base indicates that industry has also been the fastest growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1977–1986. Table 3 focuses on two relationships: first, every sector except the "other nonprofits" tends to grow somewhat more slowly as a performer than as a source of funds;* and, second, the fact that this differential exists indicates a lack of support for the thesis that Federally funded R&D is being transferred to Federal laboratories.

TABLE 3. SECTORAL GROWTH RATES IN FUNDING AND PERFORMING R&D, 1977–1986

	1977 = 100.0%	
Sector	Source	Performer
Total United States	277.2	277.2
Federal Government	255.9	232.9
Industry	303.0	291.7
Colleges & Universities	281.5	260.5
Other Nonprofit	204.6	227.4

Source: Derived from Table 1.

Battelle projects considerable differences among the 1986–87 sectoral growth rates. Total R&D expenditures are expected to grow by 7.4 percent; industrial funding and performance are expected to increase by 7.2 and 7.6 percent, respectively.

Industrial funding is expected to rise from an NSF estimated level of almost $59,500 million in 1986 to over $63,750 million in 1987. Industrial performance will rise from $87,000 million to over $93,600 million. Note that the increases in both funding and performance by industry are smaller than in previous years, as had been anticipated in the 1986 Battelle forecast.

*Although this appears to be a mathematical anomaly, it results from substantial differences in the two weighting patterns.

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority. In view of (1) the continuing emphasis on innovation; (2) the application of advanced control technology to mature industries; and (3) continued tax incentives for industrial R&D, Battelle's 1987 forecast continues a new area of analysis, namely, the comparative Federal and industrial funding of R&D in major groups of industries.

Using data derived both from NSF sources and from interpolation or extrapolation of the McGraw-Hill surveys, we have estimated the degrees to which industrial and Federal funds will support industry R&D performance (see Table 4).

This distribution between Federal and industrial funds is, unfortunately, somewhat misleading because it does not address the more critical question of support for R&D among different lines of business. With R&D expenditures grouped according to major Standard Industrial Classification (SIC) codes, it is not possible to distinguish, for example, electronics research performed by a well-known electronics company from that performed by a subsidiary of a major company whose principal product line (and SIC code) falls into an entirely different category. Conversely, this determination does not isolate, for example, research in chemicals which is performed within the rubber or petroleum industries.

More specific information on the R&D expenditures within industry is extremely difficult to collect and assess especially in those cases where (1) individual companies are engaged in a variety of research programs to support different lines of business, or (2) the company R&D is diversified among an array of products and processes within the same line of business. The extension to the case where both industrial and Federal moneys are involved is similarly difficult. Detailed data are available relative to government support of R&D by industry and by area of research. However, the comparison with expenditures of industries' own funds cannot be pursued without dissecting specific industrial R&D budgets.

These latter are, of course, almost always considered as confidential and proprietary information. Over the past few years, Battelle programs have been directed toward analyzing R&D within broad industrial classes, and thereby providing specialized information which assists in the R&D planning, management, and assessment activities of the cooperating industries. It will be quite some time, however, before sufficient detail is collected for a large number of

TABLE 4. ESTIMATED SOURCES OF FUNDS FOR R&D BY BROAD INDUSTRIAL CLASSES, 1987
(Millions of Current Dollars)

	Federal Funds	Industry Funds	Total Funds	% Federal
Aerospace	17,588	5,968	23,556	74.66
Electrical Machinery & Communications	7,396	13,958	21,354	34.63
Chemicals	315	10,508	10,823	2.91
Machinery	1,045	9,083	10,128	10.31
Autos, Trucks & parts, & Other Transportation Equipment	1,621	7,034	8,655	18.72
Professional & Scientific Instruments	751	5,382	6,133	12.24
Petroleum Products	19	2,338	2,357	0.80
Rubber Products	173	1,049	1,222	14.15
Food & Beverage	0	1,043	1,043	0.00
Paper/Pulp	3	812	815	0.36
Fabricated Metals & Ordnance	43	745	788	5.45
Stone, Clay & Glass	92	629	721	12.76
Nonferrous Metals	178	502	680	26.17
Iron & Steel	185	458	643	28.77
Textiles	0	166	166	0.00
Other Manufacturing	19	882	901	2.10
Total Manufacturing	29,428	60,557	89,985	32.70
Nonmanufacturing	1,526	2,116	3,642	41.90
TOTAL	30,954	62,673	93,627	33.06

R&D-intensive industries, and for a more nearly accurate picture of the government/industry split—with all its implications—to emerge.

As a special continued feature, this year's Forecast will deal with a different aspect of this problem in the section entitled Estimation of Sectoral R&D Activities.

The performance of R&D by industry will be financed either by the Federal government or by industry itself (Tables 2 and 4). Industrially funded work will mostly be done by industry either internally or contracted out to other industries. A very small amount (less than 2 percent) will be done extramurally by universities and other nonprofit institutions. The nonmanufacturing industries perform relatively little R&D and, as noted in Table 4, approximately 42 percent of the support for this activity is provided by the Federal government. In contrast, R&D is more heavily self-funded by (and in) the manufacturing industries where, on the average, about 33 percent of the total performance is supported by Federal funds.

The leading industry in the nation for R&D will again be the aerospace industry, projected to spend approximately $23.5 billion, with almost three-fourths of its funds coming from Federal sources. In second place will be the electrical machinery and communications industry, projected to spend almost $21.4 billion, of which 34.6 percent is Federally funded. Since 1980, these two major sectors have dominated and interchanged between first and second place. Further appropriations for defense systems, as well as anticipated growth in the computer and communications industries, are expected to continue the dominance of these two broad industrial classes.

Aside from aerospace, where Federal support of R&D is dominant, there are no industry groups in which more than half of the R&D performance is expected to be directly supported by Federal grants and contracts. In addition to electrical machinery, communication, and the combined primary metals industry (27.4 percent), no other industries receive as much as 19 percent of their funding from Federal sources.

Finally, we call attention to the fact that the total industry funding shown in the third column of Table 4 makes no distinction between R&D performed in-house and that contracted out to other industrial firms.

Factors Affecting Future Industrial Support

Over the past few years, industrial spending on R&D has increased significantly although, as anticipated in last year's Forecast, the rate of increase in 1987 will be slightly lower. Recent spurts in industrial support have been the

result of a healthier economy, increased sales and profits (both early indicators of R&D fund availability), relaxation of perceived barriers to cooperative research, and—to a small degree—the R&D tax credit enacted in 1981.

The R&D tax credit was the subject of considerable recent debate and heavy lobbying efforts during the development of the new tax package. But despite the provisions which were included in the newest version of the law, we do not expect that the tax credit will have a significant impact on industrial R&D spending. For those industries or firms which have developed R&D capabilities and have adopted a continuing R&D posture, the tax credit will not influence the decision to maintain and pursue R&D as a strategy for growth, diversification, and survival. Conversely, those who view the credit simply as a tax credit—especially with the more restrictive definition of allowable deductions—are not likely to take advantage of the provisions in the tax code.

In any discussion of the tax credit, the most important question involves the extent to which R&D spending is influenced by the tax credit itself, as opposed to the realization that R&D is necessary for long-term profitability and survival. The concept of "reindustrialization" was dominant in the headlines just a few years ago; now "competitiveness" is the rallying cry for 1987. These are essentially the same thing. Much has been written regarding the competitiveness of U.S. industry, particularly with regard to such large-volume and highly visible items as automobiles, steel, textiles, or shoes. To no small degree, industry has responded to these challenges through an intensified research effort, believing that an expansion of knowledge is one of the keys to long-term viability. The total U.S. industrial research enterprise has grown to be unequalled throughout the world, spurred on by both industrial and government policies and needs. However, there are major shortcomings in industry's ability or willingness to implement that knowledge. The combined complications of tax advantages and disadvantages; the substantial investments required for upgrading of old and obsolete plant and equipment; the competition for investment dollars; the competing and often devisive goals of labor and management; and the short-term perspective of all involved parties do not auger well for future economic strength and growth.

We can add to this a general looking to government to resolve problems through bailouts, import quotas, and other preferential treatment (at a time when government must cope with growing budget deficits). It becomes apparent that industry will have to address its own problems; that dying industries must change either their habits or their business; and that government assistance will come more in the form not of what government will do, but of what government permits others to do. Perhaps the best examples of this have been its permitting more cooperative research and its continuing effort to define and implement new patent policies.

Finally, attention must be paid to the impact on R&D of industrial restructuring. The past few years have seen a significant increase in the numbers of mergers, acquisitions, and take-overs which have been made in the name of efficiency, of consolidation of markets, and of short-term profitability. These motives are not necessarily spurious or bad, but they can lead to adverse consequences. Intra-industry mergers of similar companies generally affect R&D levels by reducing duplication of effort. Inter-industry mergers which take advantage of complementary markets and synergistic R&D efforts can have the opposite effect—a real increase in R&D effort, competitiveness, product quality, market share, and/or profitability.

However, "restructuring" often is a euphemism for selling off or disbanding activities which do not show the potential for immediate short-term profits. This places a company and its R&D efforts at risk. The major benefactors of such actions are the manipulators, rather than the innovators, and the long-term competitiveness of the company or industry may be sacrificed.

It had been hoped that this short-term outlook was being discarded during the latter part of the last decade and the first few years of the 1980s. However, it appears that the attitude may be alive and well. If this is indeed the case, we can expect reductions in the rate of growth of industrial R&D, and an adverse impact on competitiveness, both of U.S. industry and of the nation.

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct research funded by Federal agencies and/or industrial firms. It is generally conceded that a significant portion of all basic research is conducted in this sector, as well as some of the longer maturing applied research.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9.5 percent of the total. For 1987, Battelle forecasts that these same nonprofits will provide 3.3 percent of all funding and will perform almost 15 percent of the total (see Table 2). These percentages are slightly higher than the corresponding ratios for the 1986 NSF estimates.

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector.

In 1960, the academic community accounted for 55.4 percent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1987, Battelle forecasts 65.5 percent and 81.3 percent, respectively. A significant portion of the increase in academic support and performance derives from the increase in major industrial support ("directed endowments") associated with specialized areas of research such as electronics, artificial intelligence, and biological sciences.

There are two distinct groups of "other" nonprofit organizations, the *foundations* which exist primarily for charitable purposes and the *nonprofit research centers* which may or may not perform under contract. The first group funds a great deal of research, primarily through the mechanism of grants; and these grants go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: a member may perform as a foundation; it may fund its own research performance; and/or it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1987, Battelle estimates that the other nonprofit sector will comprise 2.8 percent of total R&D performance. Furthermore, we estimate that 55.2 percent of other nonprofit funding will go to colleges and universities, with the remaining 44.8 percent being spent by the other nonprofit sector itself. The percentage of support to colleges and universities is slightly higher than in recent years.*

The total R&D performance in the other nonprofit sectors is not increasing as rapidly as in other performing sectors. However, as noted above, this sector is composed of quite diverse constituent organizations. As performers of R&D, the establishments within this sector range from institutions such as Battelle (engaged in a broad spectrum of programs in the classic science and technology fields, in economics and other social sciences, and in research and technology management) to small nonprofit firms that act as delivery mechanisms and research arms for Federal, state, or local government agencies, especially for social programs.

The activities of these latter types of organizations have been significantly curtailed in recent years. Hence, it is not unexpected that the aggregate of nonprofit performers should display smaller-than-average growth rates, or, in fact, real declines in comparison with other performing sectors.

Finally, in addition to contracts or grants to support research on industrial problems (the "industry funding of colleges and universities" shown in Table 2) there is another form of support, not yet reported in detail by the NSF, that must be noted. This is the industry/university arrangement which takes a form that more nearly resembles "directed endowments" than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for as college and university self-funding.

Somewhat displaced in the accounting for industrial support of university-based R&D is the recently growing trend of major industrial gifts to universities. While industrial support of R&D, as reported by the NSF, is largely defined to include only contracts and grants with specific projects, this definition neglects the substantial funds that are used to "endow" an area of activity (e.g., robotics or biotechnology). Such funds are treated in much the same manner as state government appropriations to public institutions; that is, they become the university's "own funds" and are not credited to their real sources. This lack of better definition serves to hinder investigation of the impacts of tax laws or other incentives on the university/industry interface.

Although major endowments of universities or individual departments may accomplish objectives that are important both to academia and to industry, not all such partnerships have been welcomed. On the positive side, these programs may foster advanced university research and industrial access to faculty and graduate students. Furthermore, they provide a mechanism for promoting graduate research and education, countering a trend that has been disturbing to both the universities and industry. On the other hand, there continues to be some reluctance toward the development and concentration of university research programs in areas closely tied to potential commercial ventures. The academic community may be willing to develop patents and possible commercial spinoff industries, but there is certainly less enthusiasm for creating situations in which industry might dictate university policy. Industrial reluctance for these arrangements derives from the difficulty of maintaining proprietary claims and confidentiality with respect to the findings of industrially sponsored research. The slow but continuing growth of this form of funding suggests that these "mutual concerns" either have not developed or are being resolved.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the price of goods and services

*We must be cautious in drawing conclusions from the available data on R&D in the university and other nonprofit sectors. The primary survey data from which we work have not been collected directly for a number of years. The NSF data are fairly good estimates, but small differences can give rise to significant percentage errors.

that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly and in the same proportions, and if individual incomes also rise in those same proportions, the relationship between money and goods/services changes in a fashion which is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur which may be quite painful to particular sectors of the economy.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices, i.e., the prices of tangible things. The tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality. That is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. As a result, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry", is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output; and we therefore cannot ascertain whether or not the "price" of R&D *output* is rising or falling. We can put a price on R&D *inputs*, however, and for that reason most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measurement of R&D output, and from time to time has undertaken investigations which may lead to the quantification of at least some kinds of R&D output. Nevertheless, such a measurement is not now available and the discussion which follows must be in terms of input costs.

In viewing the costs of R&D performance, it is tempting to contrast the "inflation" in R&D with the commonly used Consumer Price Index (CPI)—the factor which provides a measure of general inflation—or to use the Gross National Product (GNP) deflator, as NSF does. To do so misses three basic points distinguishing R&D from the more general set of purchases. First, the CPI is based upon the average "marketbasket" purchased for general consumption, and the GNP deflator covers a somewhat broader range. However, purchases by R&D performers are from a much more specialized collection of goods and services.

Second, the education of scientists and engineers has a built-in bias for the acquisition and use of more sophisticated (and, hence, generally more expensive) materials, devices, and systems required for the conduct of research. Were it not for this factor of the research culture, technological advancement would not be so rapid.

Third, and perhaps most important, the very nature of research is such that the problems addressed by researchers are increasingly more difficult. The easy questions are always answered first; and the effort necessary to make incremental gains in the understanding and application of science and technology is ever-increasing. Thus, we expect that the "inflation rate", as applied to the conduct of R&D, will increase more rapidly than that of the average consumer purchases.

The "Cost of R&D Input" Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs. Battelle researchers, therefore, feel that the GNP deflators probably have misstated recent rates of inflation with respect to R&D.

Several attempts have been made in the recent past to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort to more directly measure trends and fluctuations in the cost of R&D was made by Helen Milton* beginning in 1966. Using information supplied by representative R&D performers, Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.** Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979 Battelle extended the Milton Index series by means of annual estimates. Finally a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis.

*See Helen S. Milton, "Cost of Research Index, 1920-1970", *Operations Research*, 20, 1-18 (1972).

**Milton said on p. 1, "The 'technical man' is the professional scientist or engineer, plus his support".

This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions of it.

The Battelle Cost of Research Index, displayed in Table 5, is based upon two series regularly published by the NSF: (1) the R&D performance figures, by sectors, that have already been discussed in connection with the Source/Performer Matrix (Table 2); and (2) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists/engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all sector average.*

As derived from Table 5, Battelle's best estimates of recent increases in the total index are 7.7 percent for 1983-84, 6.3 percent for 1984-85 and 4.3 percent for 1985-86. We expect the cost of R&D to increase by about 3.0 percent between the estimated 1986 level (127.47) and the forecast level for 1987 (132.67) with the estimates stated in terms of the 1982 base.

Sector Comparisons of R&D Costs

During the interval 1982-87 costs of all R&D, as an average, are estimated to have risen by 31.25 percent. Increases in the individual performing sectors are expected to be: Federal government, 55.62 percent; industry, 28.15

*Although this appears to be a mathematical anomaly, it results from substantial differences in the two weighting patterns.

TABLE 5. BATTELLE COST OF RESEARCH INDEX* BY PERFORMING SECTORS, CALENDAR YEARS 1960–1987 (1982 = 100.00)

		Performing Sectors			
Year	Total U.S.	Federal Government	Industry	Colleges and Universities	Other Nonprofit
1960	28.55	23.02	30.75	20.55	35.27
1961	29.28	24.07	31.10	23.27	36.21
1962	30.32	25.60	31.76	25.99	38.34
1963	32.35	26.49	34.03	28.87	37.50
1964	34.42	31.50	35.43	31.89	36.11
1965	35.36	32.85	36.22	33.31	37.09
1966	36.80	33.02	38.00	34.23	39.61
1967	37.87	34.03	39.08	35.34	41.27
1968	39.43	34.39	40.80	37.57	43.15
1969	40.55	34.57	42.24	37.72	45.69
1970	42.37	40.87	42.86	40.24	47.88
1971	44.21	43.73	44.53	42.34	47.22
1972	48.47	49.06	49.15	44.20	48.62
1973	52.31	51.74	53.40	47.86	50.45
1974	55.65	54.17	57.12	49.22	58.29
1975	58.76	60.17	59.15	54.44	61.76
1976	63.66	65.96	64.05	58.96	64.91
1977	67.14	69.23	67.35	63.58	68.78
1978	72.51	78.29	71.53	71.44	74.46
1979	78.70	83.93	77.29	79.73	84.73
1980	85.08	85.48	84.39	88.04	87.04
1981	93.09	93.41	92.41	96.33	94.84
1982	100.00	100.00	100.00	100.00	100.00
1983	106.93	114.42	105.77	106.62	108.30
1984	115.04	124.26	113.69	114.10	118.29
1985	122.24	140.34	119.88	120.92	122.66
1986	127.47	148.69	124.84	127.27	122.11
1987	132.67	155.62	130.03	133.17	122.30

*Costs of performing R&D per scientist/engineer (full-time equivalence).
Source: Estimated by Battelle from NSF and Battelle data.

percent; colleges and universities, 33.17 percent; and other nonprofit, 22.30 percent. As noted, the 1986-87 cost increase for all R&D is estimated to be 2.96 percent. By sectors, the increases are estimated as Federal, 4.66 percent; industry, 2.65 percent; colleges and universities, 4.63 percent; and other nonprofits, 0.15 percent.

Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1982 dollars with the corresponding index numbers from Table 5, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 6 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded $62 billion for the first time in 10 years. We expect real R&D effort in 1987 to increase by 4.3 percent over 1986 and to reach a level that is 52.3 percent above its 1969 peak.

When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sectors. The downturn or flat behavior in real expenditures that began after 1968-69 is clearly reflected by every sector.

TABLE 6. CURRENT AND CONSTANT DOLLAR (1982 = 100) R&D EXPENDITURES IN THE U.S., 1960–1987, BY PERFORMERS

(All Amounts in Millions of Dollars)

	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofits	
Year	Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1960	13,523	47,356	1,726	7,496	10,509	34,168	1,006	4,893	282	799
1961	14,316	48,889	1,874	7,785	10,908	35,067	1,173	5,040	361	997
1962	15,394	50,761	2,098	8,193	11,464	36,090	1,374	5,285	458	1,195
1963	17,059	52,728	2,279	8,600	12,630	37,112	1,611	5,578	539	1,437
1964	18,854	54,774	2,838	9,008	13,512	38,135	1,904	5,970	600	1,662
1965	20,044	56,673	3,093	9,415	14,185	39,158	2,103	6,312	663	1,787
1966	21,846	59,362	3,220	9,750	15,548	40,911	2,345	6,851	733	1,850
1967	23,146	61,110	3,396	9,979	16,385	41,923	2,594	7,340	771	1,868
1968	24,605	62,387	3,494	10,158	17,429	42,709	2,868	7,634	814	1,886
1969	25,631	63,194	3,503	10,131	18,308	43,339	2,950	7,819	870	1,904
1970	26,134	61,673	4,079	9,979	18,067	42,148	3,072	7,634	916	1,913
1971	26,676	60,328	4,228	9,667	18,320	41,136	3,216	7,594	912	1,931
1972	28,477	58,741	4,590	9,354	19,552	39,776	3,383	7,653	952	1,958
1973	30,718	58,714	4,762	9,202	21,249	39,787	3,701	7,731	1,006	1,994
1974	32,864	59,052	4,911	9,065	22,887	40,068	3,888	7,898	1,178	2,021
1975	35,213	59,926	5,354	8,897	24,187	40,889	4,396	8,074	1,276	2,066
1976	39,018	61,282	5,769	8,745	26,997	42,148	4,876	8,270	1,376	2,120
1977	42,783	63,714	6,012	8,684	29,825	44,283	5,451	8,573	1,495	2,174
1978	48,129	66,374	6,811	8,699	33,304	46,553	6,342	8,876	1,672	2,245
1979	54,933	69,793	7,417	8,836	38,226	49,453	7,296	9,150	1,994	2,353
1980	62,593	73,567	7,632	8,928	44,505	52,735	8,306	9,434	2,150	2,470
1981	71,840	77,165	8,425	9,019	51,810	56,062	9,305	9,659	2,300	2,425
1982	79,328	79,328	9,141	9,141	57,995	57,995	9,767	9,767	2,425	2,425
1983	87,178	81,522	10,582	9,248	63,403	59,939	10,518	9,865	2,675	2,470
1984	97,379	84,645	11,586	9,324	71,227	62,648	11,591	10,158	2,975	2,515
1985	108,800	88,999	13,150	9,370	79,500	66,312	12,900	10,667	3,250	2,650
1986	118,600	93,040	14,000	9,415	87,000	69,684	14,200	11,157	3,400	2,784
1987	128,780	97,066	14,700	9,446	95,000	73,056	15,510	11,646	3,570	2,919

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle Cost of Research Index of Table 5.

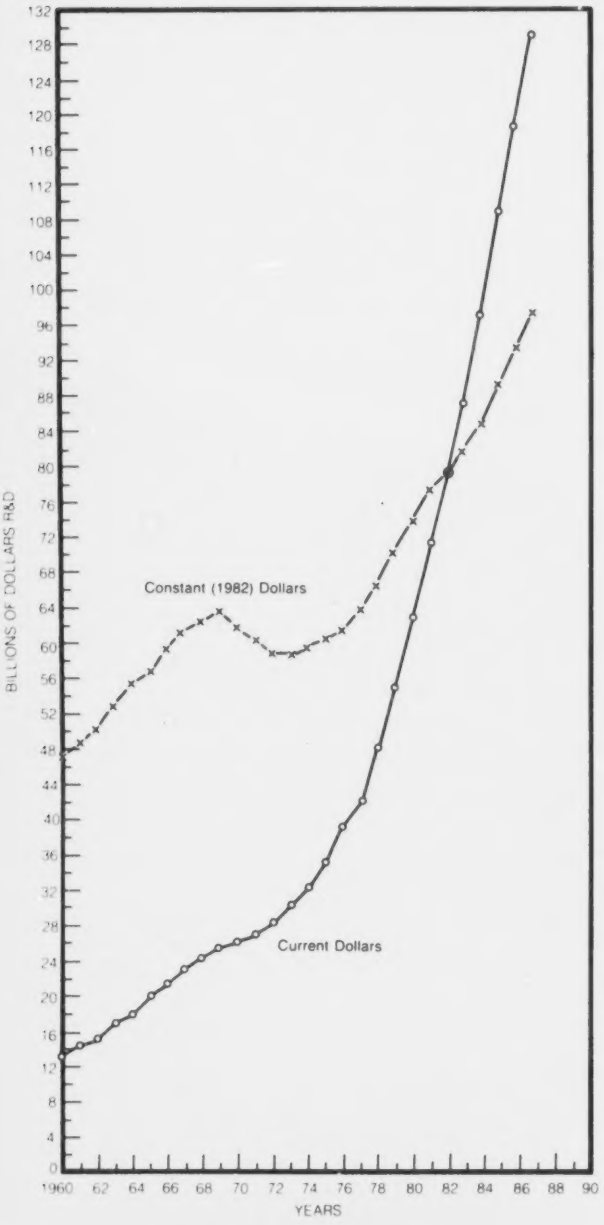

FIGURE 3. TOTAL R&D EXPENDITURES, 1960–87, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1982 = 100%)

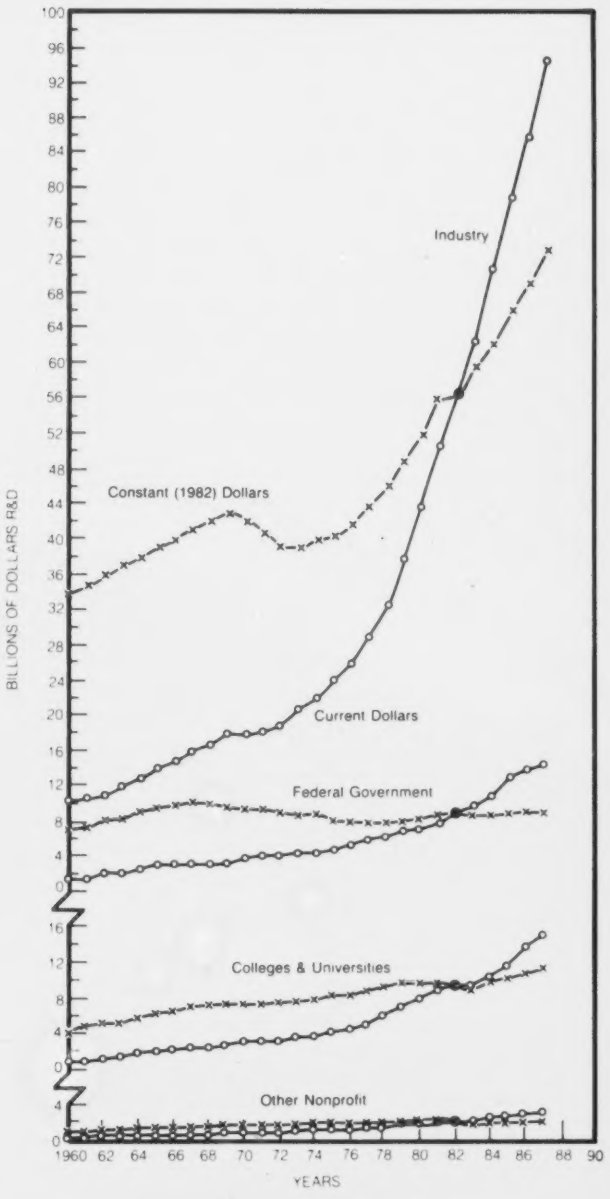

FIGURE 4. R&D EXPENDITURES BY SECTORS, 1960–87, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1982 = 100%)

However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has recovered only slowly from its 1977 minimum and has not yet equalled its 1969 peak.

In the private sectors, industry reached its real low in 1972 and has since risen by 84 percent to its highest recorded value. The academic community reached its low in 1972. Since then, its real performance has risen by over 52 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined slightly from 1968 through 1970. Since that time it has risen by 55 percent.

Finally, we turn to the data of Table 6 and the curves of Figures 3 and 4 to see the dramatic differences in the R&D trends among the four performing sectors. Since the lull of the early 1970s, industrial performance, funded by both government and industry, has been largely responsible for the real growth within the R&D enterprise. Using the same performance deflators as applied to the sources of funds, it is seen that over the past decade, industrial support of R&D has increased at an average compounded rate of 5.49 percent per year, while Federal support has increased at 2.05 percent per year on average.

The behavior exhibited in Figures 3 and 4 suggests that the real growth in R&D (and the economic development and expansion that result from it) has come from the applied research supported and performed by private industry. However, one cannot overlook the fact that such applied research and development must rest on, and evolve from, the basic research foundation—an activity that is primarily supported by the Federal government (almost 64 percent).

Over the past few years, Federal support has tended to shift more toward "development" and less toward basic and applied "research".* The Federal government is still the major supporter of basic research, and trends in the Federal budget indicate that this support will continue to be strong. In addition, there is a continuation of basic research support by industry. However, the volatility of those indicators (sales, profits, cash flow) which influence industrial R&D budgets precludes the stability needed for long-term planning. Policy- and budget-makers in all funding sectors should note very carefully the trends in basic research, since the conduct of such research forms the basis for future economic vitality and competitiveness.

Thus, the Federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should continually re-examine its policies relative to (1) the support of R&D, (2) the roles of the public and private sectors, (3) the factors which enhance or impede the progress of science and technology, and (4) the commitment to science education at all levels. Such examination will most likely be clouded by pressures imposed by budget-cutting activities and the politics of short-term gains.

A Look Toward 1988 and Beyond

While former issues of the Battelle *Forecast and Analysis* (through the 1983 edition) had been confined to considerations of the forthcoming year only, well-established commitments by both the Federal government and industry permit a longer look at the R&D forecast. Judging from recent trends in government spending, long-term budget commitments (tempered by budget-cutting activities), and the existing overall business climate, it is estimated that 1988 sources for R&D will be:

Federal government	$ 62,300	million
Private industry	67,620	million
Colleges & universities	3,050	million
Other nonprofit organizations	1,510	million
TOTAL	$134,480	million

In addition, it is estimated that 1988 expenditures of R&D will be distributed among the four performing sectors as follows:

Federal government	$ 15,200	million
Private industry	99,000	million
Colleges & universities	16,550	million
Other nonprofit organizations	3,730	million

The overall 5.5 percent increase in funding and performance (expressed in constant 1987 dollars) will be unevenly spread among funding and performing sectors. It is expected that funding and performance by both the Federal government and the other nonprofit sectors will increase more slowly than average, while industrial and university funding and performance will increase more rapidly.

The trends which pointed to a slowdown in the rate of growth, noted in last year's Forecast, are expected to continue. While Federal funding of R&D had increased substantially—largely influenced by defense programs—the growing Federal deficit was beginning to take its toll. Although neither Congress nor the Administration had been willing to come to grips with the problem, it was inevitable that new, and perhaps unpopular, actions would be required. Huge defense buildups plus reduced taxes, plus a balanced budget could not, and did not, occur. To a significant degree, the passage of the Gramm-Rudman-Hollings Bill has forced reductions in the rate of growth of expenditures. We expect that the rate of growth will continue to slow, although some real growth in Federal spending will occur.

The picture regarding industrial R&D growth is a little more difficult to decipher, since other kinds of forces have an influence. Federal policies certainly affect industrial decision-making. Action or inaction relative to increased private and corporate taxes, limited import duties or other protectionist measures, R&D tax credits, patent policy, and cooperative research will continue to affect industrial

*One must be careful not to read too much into the data which are available regarding the divisions among basic and applied research, and development. It is at times difficult to make the distinction as to where one phase stops and the next takes over. Furthermore, the definition as applied by the supporter may be substantially different from that applied by the performer.

commitment to R&D, as they have in the past. These generally act more as small perturbations on the more important driving forces for industrial support of research and development, namely, (1) the need to respond to competition (both foreign and domestic) and (2) the availability of funds from earlier years' sales and profits.

Increases in university self-funding and performance in the near future are, in part, a consequence of increased industrial actions of the recent past. The relaxation of apparent barriers to industrial cooperation created a funding mechanism which has infused substantial additional resources to the college and university sector. Counted as the sector's "own funds", this form of R&D support and performance will most likely continue to grow slightly over the next few years. However, it is also quite possible that a period of disenchantment will set in, particularly if either of two factors comes into play: (1) if the universities feel an encroachment upon their independence and sovereignty; or (2) if supporting industries are unable or unwilling to reduce research to applications and profit. If either of these conditions comes to pass—and the next five years is the critical period—the industry/academia honeymoon may be merely an anomaly in the broader picture of long-term relations.

The total support of R&D involves an obvious "partnership" between government and industry in terms of both the levels of support and the division among basic research, applied research, and development.

In addition, the development of technologies that have obvious applications in defense, space, health and other Federal concerns has significant implications in terms of industrial growth and competitiveness. Thus, continuing efforts have been made to promote greater cooperation between Federal laboratories and the private sector. These efforts have not paid off as hoped. In many respects, this results from a lack of understanding of the incentives of both the providers (Federal laboratories) and the users (private industry).

The national commitment to continued support and growth of R&D is based upon the (usually non-quantifiable) observation of the positive impacts of past actions. Each funding and performing sector—individually and in concert with the others—has made major contributions to the economic strength and security of the nation. Furthermore, this cooperative effort has permitted the assumption of a pre-eminent position among the nations of the world.

But as technological advances are made, a greater effort should be pursued to look at the long-term implications of R&D. There are many difficult questions that must be addressed, including considerations of the educational system, the potential displacement of skilled and unskilled laborers, the impacts of increased life expectancy, and the general changes in the delivery of all manner of goods and services. Government and business alike have a responsibility to take the longer view, to assess the impacts of technological change, and to develop alternative postures that can assure that the benefits of technological change can be realized without serious disruption to the society.

Estimation of Sectoral R&D Activities, 1987

As noted in an earlier section of this forecast, the distribution of industrial R&D according to the broad categories (as seen in Table 4) is likely to be misinterpreted. The classification of enterprises in terms of their principal lines of business totally neglects the fact that many diverse companies conduct research in many diverse areas: for example, oil companies do research in chemicals; chemical companies conduct programs in electronic materials; electronics companies do research on glass; and glass companies are involved in studies of construction technology.

Although Battelle has initiated programs which address the question of line-of-business R&D within selected broad industries, there are no reliable compilations of data which provide details on the levels of R&D in, for example, chemicals, rubber and plastics, electronic materials, or machinery. However, an indirect approach has evolved from other Battelle work and an initial estimate of R&D distribution can now be put forward.

After several years' work on the inclusion of R&D activity in Battelle's Input-Output (I/O) model of the United States economy, it has become possible to use this material as an alternative basis of R&D forecasts, and as a source of increased industry detail in ascribed R&D.* Therefore, we are including a brief description of the I/O modeling method in the 1986 Forecast & Analysis, along with an indication of the new information it provides. Work will continue on this approach in the hope that it can provide a major expansion in future annual forecasts.

Underlying Assumptions and Concepts

The I/O approach to the projection and analysis of R&D activity includes several underlying assumptions and/or conceptions:

- R&D is sufficiently homogeneous across fields of applications to be treated as an I/O *sector*—that

*We cannot, in this space, provide detailed information on Input-Output modeling. Those who are not generally familiar with this approach to economic forecasting and analysis may request a copy of the Battelle monograph, *A Businessman's Introduction to Input-Output*, by W. Halder Fisher and P. Israilevich (Economics and Policy Analysis Occasional Paper No. 45, February, 1984).

is, as an activity which "sells" its outputs to other product- or process-related activities.

- Regardless of whether purchased extramurally or performed intramurally, R&D can be treated as a productive input into the sector which performs it, purchases it, or benefits from it in special ways.
- The average cost-structure of R&D activity across the whole economy can be ascertained and will be reasonably relevant to any R&D-using (or R&D-procuring) sector.

On the foundation provided by these sets of assumptions, two R&D sectors were incorporated into an expanded 150-order version of the Battelle I/O model for use in a special application (the so-called "Cost of Fracture" report).* The "fracture model" was established to describe an economy comparable to that of the United States in 1978. The present, modified 130-order model is general, not fracture-specific, and is intended to describe an economy technically comparable to the United States in 1985.

Sources of Data

In the form we use, there are three crucial data inputs to the model: (1) the ratio of R&D to sales in each sector; (2) the structure of the total domestic economic activity [expressed in terms of sectoral Total Domestic Outputs (TDOs)]; and (3) estimated GNP for the target year. The sources used in the present model applications were those originally used for the "fracture study" as modified and/or updated into its current, more generalized form.

The R&D/Sales Ratio. These data were originally established in the form of technical coefficients of the fracture model and were generated from the expert knowledge and/or opinions of selected industry specialists. In modifying them to their present form, they have been adjusted and updated by reference to company and industry R&D/sales ratios reported in the *Business Week* Industrial Scoreboard.**

On the basis of these data, the R&D coefficients were re-formatted, modified and updated. However, both the original set of values and their present modifications involve judgmental, as well as statistical, determinations.

The Structure of TDO. The total outputs of the industrial sectors for any I/O model, when summed across the entire economy, involve a certain amount of multiple counting. The exact degree of multiple counting depends on the number of sectors into which the economy is divided, on the technologies of each sector, and on the sectoral (industrial) composition of economic activity. At this point, our interest is confined to the last of these three elements.

The industrial structure of the economy, as used here, is measured in terms of the sectoral ratios, Sector TDO/TDO, which sum to unity. The only currently available source from which these structural data can be derived are the values of Total Domestic Output reported in the 1978 fracture model.

Dollar Levels of Economic Activity. The best single-counted measurement of annual economic activity is provided by the GNP, officially reported by the Department of Commerce in its *National Income and Product Accounts* (NIPA). The latest year for which a "solid" official estimate of GNP is available is 1984. Thus, the 1986 value was estimated by Battelle to be $4,399 billion.*

In order to obtain a multiple-counted summation of TDO for 1986, the estimated GNP has been multiplied by the ratio [Sum]TDO/GNP = 1.6, which characterizes all 1978 and later Battelle I/O tables at this general level of detail.

Some Preliminary Findings

The procedure described above has generated preliminary estimates of total sales activity, R&D performance/ascriptions, and ratios of R&D to total sales for each of 130 industrial sectors, and for unascribed R&D in final demand. This provides a much more detailed distribution of R&D activity and/or benefits than those previously available from NSF, McGraw-Hill, or even earlier Battelle forecasts. Since the I/O sectors used in this model are defined in terms of pure processes, rather than company or establishment SIC classifications, these R&D details are mainly in line-of-business terms.

The total preliminary estimate of 1986 R&D, as calculated from this approach, is $115.88 billion, almost equal to that derived by an entirely different approach and cited earlier in this Forecast.

Broad Category Distribution of R&D

Although the Battelle I/O model is split into 130 sectors (this number varying dependent upon the specific programs to which the model is applied), these sectors can

*J. J. Duga, et al., *The Economic Effects of Fracture in the United States*, U.S. Department of Commerce, National Bureau of Standards, Special Publication 647-2 (March, 1983).

**See *Business Week* Industrial Scoreboard, June 27, 1986, pp. 134-156.

*This value has been interpolated between 1985 and 1990 estimates made by Battelle, as reported in *FIVE BASICS DESCRIPTOR ESSAYS: Selected Economic, Technological and Political Trends Analyses to 1995*, by W. Halder Fisher and Stephen D. Millett (Economics and Policy Analysis Occasional Paper No. 50, May, 1985).

be conveniently grouped into 20 broad categories. Many of these categories are similar to the broad industrial groupings used by NSF and McGraw-Hill in their reportings of R&D activity. However, these groups of lines of business do not necessarily embrace the same business activities as do their SIC counterparts which bear the same or similar titles.

Table 7 shows the distribution of business-related R&D activity over these 20 broad categories, while Tables 8, 9 and 10 list the 10 largest sectors ranked, respectively, in terms of total sales, total R&D expenditures, and R&D as a percent of sales. Similar tables including all 130 sectors are available upon request.

The approach employed in this estimate provides more detail relative to R&D expenditures within much narrower categories than had been previously available. While the results are subject to a compounding of errors inherent in the estimation techniques, this approach offers a means whereby diversified companies can begin to compare their total research efforts in comparable terms. Furthermore, it is important to note that the use of the *technology-based* I/O model, and the inclusion of a separate R&D sector, permits an assessment of the impacts of various technology-driven "what-if" questions.

Finally, the I/O model method addresses the *total* R&D conducted in the United States, not just that which is performed by industry (as in Table 4). Government-funded programs in chemicals, for example, are ascribed to the sector which accounts for the technology of chemicals production, rather than to the industry or company which conducts the research or markets the final product.

TABLE 7. DISTRIBUTION OF BUSINESS SALES AND R&D ACTIVITY ACROSS BROAD CATEGORIES OF THE ECONOMY, UNITED STATES, 1987

Industrial Grouping	Total Sales (millions of dollars)	Total R&D (millions of dollars)	Percent of Business Total: Sales	Percent of Business Total: R&D	R&D as a Percent of Sales
Agriculture, Forestry, Fisheries	224,420	3,670	3.11	3.72	1.63
Mining & Quarrying	219,230	5,190	3.03	5.26	2.36
Food, Tobacco, & Textiles	640,720	5,750	8.88	5.83	0.89
Lumber & Wood Products	269,500	5,840	3.73	5.92	2.16
Chemicals & Rubber	546,350	12,270	7.57	12.44	2.24
Stone, Clay & Glass Products	99,630	1,470	1.38	1.49	1.48
Primary Metals	199,930	2,210	2.77	2.25	1.11
Fabricated Metal Products	159,140	2,270	2.20	2.30	1.42
Heavy Industry	68,970	1,790	0.95	1.82	2.60
Industrial Machinery & Equipment	122,930	4,570	1.70	4.64	3.72
Transportation Equipment	356,120	10,020	4.93	10.16	2.81
Electrical Machinery & Equipment	99,110	3,910	1.37	3.96	3.94
Special Electrical & Electronic Equipment	134,160	6,910	1.85	7.01	5.15
Scientific & Professional Instruments	41,870	2,560	0.58	2.60	6.13
Miscellaneous Manufacturing	63,510	1,500	0.88	1.52	2.36
Transportation Services	220,260	930	3.05	0.94	0.42
Public Utilities	390,800	2,610	5.41	2.64	0.66
Construction	666,300	5,290	9.23	5.36	0.79
Trade, Finance & Services	1,949,760	14,190	27.02	14.40	0.72
Miscellaneous and Repair Services	741,100	5,540	10.27	5.62	0.74
Total Business*	7,213,800	98,500	100	100	1.36

*Due to rounding, details will not add to totals.
Source: Battelle estimates (see text).

TABLE 8. R&D ACTIVITIES OF TEN LARGEST INDUSTRIAL SECTORS AT 137-ORDER DETAIL. UNITED STATES, 1987

Rank	Sector Title	Total Sales (Millions)	Total R&D (Millions)
1	Trade	771,143	3,393
2	Real Estate	581,304	221
3	Food Production	387,902	3,879
4	Constr.—Residential	264,356	1,586
5	Motor Vehicles	249,054	6,012
6	Finance & Insurance	242,648	1,211
7	Petroleum Refining	242,063	1,452
8	Const.—Nonresidential	234,344	1,406
9	Educational Services	229,244	1,375
10	Other Bus./Prof.Srvcs.	165,937	4,148

TABLE 9. TEN LARGEST INDUSTRIAL SECTORS AT 137-ORDER DETAIL, IN TERMS OF R&D ACTIVITY. UNITED STATES, 1987

Rank	Sector Title	Total Sales (Millions)	Total R&D (Millions)
1	Motor Vehicles	249,054	6,012
2	R&D	97,098	4,676
3	Other Bus./Prof. Srvcs.	165,937	4,148
4	Comps. & Off. Equipmt.	41,807	3,917
5	Pulp & Paper	130,681	3,900
6	Food Production	387,902	3,879
7	Aircraft & Missiles	67,599	3,448
8	Trade	771,143	3,393
9	Ind. Organic Chems.	63,371	2,852
10	Radio, TV, Commnctns.	46,691	2,335

TABLE 10. TEN LARGEST INDUSTRIAL SECTORS AT 137-ORDER DETAIL, IN TERMS OF R&D AS A PERCENT OF SALES. UNITED STATES, 1987

Rank	Sector Title	Total Sales (Millions)	Total R&D (Millions)	R&D as a Percent of Sales
1	Computers & Office Equipmt.	41,807	3,917	9.36
3	Drugs	24,983	1,999	8.00
3	Electronic Components	10,995	880	8.00
3	Medical, Dental, Instrumen.	5,606	448	8.00
5	Photo Equipment, etc.	9,105	594	6.52
8	Coal (surface & other)	30,228	1,814	6.00
8	Scientific Instrmnts.	20,979	1,259	6.00
8	Coal (underground)	19,010	1,141	6.00
8	Toilet Preparations	9,905	594	6.00
8	Optical Instruments, etc.	3,564	214	6.00

TECHNICAL APPENDIX

NSF DEFINITIONS OF RESEARCH AND DEVELOPMENT

Many activities, from one viewpoint or another, may be termed "Research and Development". The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"Research and development . . . consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development . . .

"Research, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"Basic research. For three of the sectors—federal government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with . . . a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represents . . . original investigations for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"Applied Research. The following is the core definition in the NSF questionnaire sent to the universities and colleges: *'Applied research* is directed toward practical application of knowledge'. Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers '. . . research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes'. By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

"Development. The NSF survey concept of development may be summarized as '. . . the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes'."*

*National Science Foundation, *National Patterns of R&D Resources*. 1953-78/79. NSF 78-313, p. 25.

ABOUT BATTELLE

Battelle Memorial Institute serves industry and government in the generation, application, and commercialization of technology. With a wide range of scientific and technical capabilities, it provides an added dimension to the research and development activities of clients in 40 countries.

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- Research—conceptual, problem-solving, and product and process development;
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Major business areas are advanced materials, biological and chemical sciences, biotechnology, electronics and defense systems, engineering and manufacturing technology, and information systems. Annual business volume exceeds $500 million.

With a staff of 7,800 scientists, engineers, and supporting specialists, Battelle has major research operations in the United States and Europe, as well as offices and representatives in many other parts of the world. Staff, facilities, and resources from all Battelle locations are available to solve problems and develop business opportunities for clients.

The Institute, which began operations in 1929, was established by Ohio Industrialist Gordon Battelle, who recognized that a constantly changing world can be improved through advances in technology and education.

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